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By Peter J. Hearst, Ph. D.

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REFLECTIVE COATINGS FOR HANGAR FLOORS: PERFORMANCE OF COATING SYSTEM DESIGNS

ABSTRACT Reflective floor coatings improve illumination in aircraft maintenance hangars but they often have poor slip resistance or lose their slip resistance and thereby pose safety hazards and maintenance problems. Coating system designs have been investigated in field trials to provide a basis for the selection of coating systems of improved performance.

NAVAL CIVIL ENGINEERING LABORATORY PORT HUENEME CALIFORNIA 93043-5003

METRIC CONVERSION FACTORS

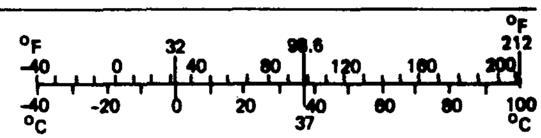
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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Reflective floor coatings improve illumination in aircraft maintenance hangars but they often have poor slip resistance or lose their slip resistance and thereby pose safety hazards and maintenance problems. Coating system designs have been investigated in field trials to provide a basis for the selection of coating systems of improved performance.

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INTRODUCTION

The Naval Civil Engineering Laboratory (NCEL) has investigated the use of reflective coatings for hangar floors. The chief emphasis of the research has been to find methods of reducing the slipperiness and increasing the longevity of the reflective coatings, and to determine the optimum designs for coating systems that provide satisfactory performance. This work was sponsored by the Naval Facilities Engineering Command (NAVFAC).

Coating system designs that were likely to provide improvements over currently used designs were submitted to an operational test at Naval Air Station (NAS) Brunswick, ME. Included were thin-film coating systems, thick-film coating systems, and organic toppings. This report discusses results of the field test on the basis of observations made at the time of coating application and measurements made soon thereafter. Because long-term performance information is not available, it is a preliminary report on this field test. Experiences with similar coating systems applied at other locations, that relate to the performance of coating system designs, also are discussed.

BACKGROUND

Reflective floor coatings are used by the Navy and the Air Force in maintenance hangars because they provide improved illumination to the undersides of aircraft. This creates a better working environment and foreign objects are more visible. Typically, these coatings are thin-film chemically resistant urethane (CRU) coating systems. The white CRU coatings are applied to concrete floors at a dry film thickness of about 8 mils (200 μm) over an epoxy primer. Two or more topcoats hold the alumina grit that is applied to provide slip resistance. Besides the thin-film coating systems, thicker coating systems or reflective organic toppings can also be used.

Properly applied, used, and maintained, reflective CRU coatings can increase the underwing illumination of aircraft fourfold. Good surface preparation and correct coating application are required to give adequate adhesion. An appropriate grit must be properly placed in the coating system to provide and retain adequate slip resistance. Careful use of the floors is important because rough or even normal use may cause substantial loss of grit, resulting in slippery floors. Cleanliness is also important because liquids on the floors make them more slippery, and excessive dirt will reduce lighting and cause greater coating wear.

One of the major problems of the thin-film reflective coatings is that the large alumina grit that is incorporated in the coating system to provide good slip resistance is dislodged in normal use and the floor becomes slippery. Good slip resistance is considered more important in military maintenance hangers than in commercial counterparts because the younger military aircraft mechanics tend to be less careful, and many slipping accidents have occurred.

COATING SYSTEM DESIGN

Reflective coatings for hangar floors can be thin-film coating systems, thick-film coating systems, or organic toppings. Various system designs are described below, and some of their potential advantages and disadvantages, are discussed.

Thin-Film Coating Systems

In the past, these systems typically have consisted of an epoxy primer, a CRU intermediate coat onto which Grit No. 30 alumina has been broadcast, and a CRU topcoat. The grit is required because the CRU coatings are inherently very slippery. Problems with these systems stem chiefly from the loss of the grit and from the difficulty in obtaining even distribution of the grit during application.

The upper two coats of the typically applied thin-film system are together about 5 mils thick and do not have a very tight hold on the alumina, which is about 25 mils in diameter. If the grit is overcoated with additional CRU topcoats and the size of the grit is reduced, the grit is held in tighter, the service life is increased, and cleaning is easier. However, this is at the expense of the slip resistance, which is reduced. The application of an increased amount of grit can offset the subsequent loss of grit and of slip resistance.

Even distribution of the grit in the coating is important. Floors with slippery areas of light grit distribution interspersed in areas of good slip resistance are more hazardous than floors of uniform low slip resistance. Premixing the grit in the coating before application, rather than broadcasting it onto the wet coating, can produce more even distribution. Alumina cannot be premixed easily because it is much more dense than the coating and will settle out rapidly unless it is very fine. Polypropylene grit is slightly less dense than the coating and can be premixed. Coating systems with premixed polypropylene can provide good slip resistance without having the roughness of the larger alumina. The polypropylene grit is softer than the alumina, and the service life of these systems has not been established.

The cost of the thin-film systems depends on the condition of the floor and on other factors including labor costs. Applied on a floor in good condition, the cost is about $1.00 per square foot.

Thick-Film Coating Systems

These systems are about twice the thickness of the thin-film systems. They hold the large alumina grit in a thick intermediate epoxy coat that provides better grit retention. Such systems had been investigated in the laboratory but had not been applied on hangar floors.

The thick-film coating systems should retain their grit, and therefore their slip resistances, for a much longer time than the thin-film coating systems. They would thus provide much longer service lives. The self-leveling epoxy primer and intermediate coats of these systems contain 100% solids and therefore do not pose the volatile organic carbon (VOC) problems that would be caused by building up the thickness with several additional CRU coats that contain solvents.

Applied to a floor in good condition, the cost of the thick-film system may be about $1.25 per square foot.

Organic Toppings

Toppings consisting of an epoxy matrix filled with sand are used industrially. For use in hangars, they may be overcoated with CRU topcoats. Such toppings can be 1/16- to 1/4-inch thick and have the potential for being more durable than the thin-film coating systems, but they are more expensive and as typically applied are not sufficiently slip resistant. Toppings may be applied with alumina instead of sand to make them more slip resistant and more durable. Toppings may present solutions to the durability problems encountered with thin-film systems. However, they require skilled applicators, and problems related to porous concrete floors, rough concrete surfaces, and improper application have been encountered.

Applied to a floor in good condition, the cost of an organic topping may range from about $1.75 to $2.75 per square foot.

FIELD TEST OF SYSTEM DESIGNS

The thin-film coating system designs selected for field testing were potential improvements over the typical system that consists of an epoxy primer, a CRU intermediate coat onto which grit no. 30 or no. 36 alumina has been broadcast, and a CRU topcoat. The selected systems with alumina grit contained grit no. 36, no. 46, or no. 54 alumina. The two systems with grit no. 36 alumina had different amounts of grit broadcast into the first CRU coat before overcoating with two CRU topcoats. The four systems using the finer aluminas had the same amounts of grit broadcast into the first CRU coat but were overcoated with different thicknesses of CRU topcoat.

The size requirements for the alumina grit used, and for some larger sizes, are shown in Table 1. The amounts of grit and the dry film thicknesses of the CRU coats in these thin-film coating system designs (Systems 4S to 6N) are shown in Table 2. In all these systems, the first coat (coat 1) was a water-based epoxy primer.

The selected thin-film coating system designs also included systems with polypropylene grit, rather than alumina. This grit, or pigment, was premixed in the CRU coat before application, rather than being broadcast. The largest commercially available polypropylene pigments were 200-μm spherical and 150-μm popcorn-shaped materials. The nominal average diameters of these pigments are about 8 and 6 mils, respectively. The amounts of grit premixed in the CRU coating and the dry film thicknesses of the CRU coats in these system designs (Systems 1S to 2N) are also shown in Table 2. Coat 1 was the same water-based epoxy primer used for the other thin-film systems.

The thick-film coating systems selected for the field test were two systems with grit no. 24 alumina in an epoxy intermediate coat. It was expected that this larger alumina grit would be better encapsulated and more tightly held in the thicker epoxy intermediate coat than the finer grit could be held in the thin CRU coat. This thick epoxy coat, with grit having an average diameter roughly twice the thickness of the coating, was overcoated twice with a CRU topcoat. These two systems (Systems 3S and 3N) are described in Table 3. Coat 1 of these systems is a thin self-leveling epoxy coating designed to provide a smooth primed surface.

Organic toppings were also included in the field test. The coating system designs of these toppings begin with a thin slurry coat applied to a smooth primed surface. The wet slurry coat is filled to excess with grit. After curing, the excess grit is removed and the resulting porous surface is filled with a minimum amount of additional slurry seal to leave a rough surface. After the latter is cured, two coats of CRU topcoat are applied. Slurry coat thicknesses of 60- and 16-mils, each filled with sand or with two sizes of alumina, were included in the six system designs (Systems 3A to 3F) selected for the field test. These are described in Table 3.

An additional epoxy coating system without CRU topcoat was also included. This coating was rolled on, like an aircraft carrier deck coating, to provide a wavy surface. The alumina filling was much finer than the alumina used on carrier decks, or in the other systems described above, and could be premixed in the wet coating before application. Both the uneven surface of the coating and the alumina were expected to contribute to the slip resistance. This coating is described as System 4A in Table 3.

The need for recoating Hangar 5 at NAS Brunswick provided an opportunity for a field test, because the Station was willing to allow the application of the various selected coating systems on the different bays of the hangar. The contract that would normally have been used was modified to allow the application of the ten thin-film systems and the two thick-film systems on different halves of six bays, and to leave bare the front portions of Bays 3 and 4 for the application of the other thick systems. The layout of the coating systems in the bays of Hangar 5 is shown in Figure 1. The floor plan of the bays is illustrated in Figure 2. (The contract also included coating of the central Bay 7 with System 4S, but this bay was not considered part of the field test because it receives different usage from that of the other six bays.)

The selection of the manufacturer of coatings used for the above 12 coating systems was left to the discretion of the applicator that won the contract award. Because this field test was a comparison of coating system designs, it was considered to be of minor importance which manufacturer's coatings were used, as long as the same primers and CRU topcoats were used for each system and as long as these coatings were known to be able to provide good performance.

Purchase orders separate from the above-described contract were placed for the applications of the coating systems at the front portions of Bays 3 and 4. The coatings used were supplied by different manufacturers, but because these coating systems differ considerably from the other systems, small differences in the formulation of the individual coatings of the systems were expected to be of relatively minor importance.

COATING SYSTEM APPLICATION

Most of the coating systems were applied during June 1988. Those at the front of Bay 3 were applied in August 1988. The surface preparation method used for all the coating systems and the application methods used for the different types of coatings are discussed below.

The alumina grit used in the coating systems met the requirements of Table 1, as shown by the results of sieve analyses presented in Table 4. The average thicknesses (T, in mils) of the CRU coats of the thin-film systems were calculated from the volumes of coating used (V, in gallons), the solids content of the coating (S, in % by volume), and the areas coated (A, in sq ft), using the formula: $T = 16*V*S/A$. These calculated thicknesses met minimum requirements or were up to 20% thicker, which is a variation that is probably less than that of typical coating applications.

Surface Preparation

All the floor surfaces had been previously coated. The existent coatings were in sufficiently good condition that it was necessary to remove only a relatively small portion of these coatings. The concrete floor was divided by joints into approximately 12-foot squares. Squares that had lost considerable coating had been designated before contract award for removal of the old coating. Removal of the old coating also was specified for all of Bay 3 and for the front four rows of squares in Bay 4.

All floor surfaces were first washed with an alkaline detergent. The old coating was then removed from the designated squares. A scarifier was used, even though scarifiers are not generally recommended because they can easily damage the concrete surface. In this case it was used by only two workmen who were very experienced and who pushed it along the floor very slowly. The scarifier had several hundred star shaped cutting wheels arranged in a drum shape. When the teeth of the cutting wheels became ground away to about half their height, they were replaced. The old wheels were used in small hand-held scarifiers that were used at the edges. The floor was very smooth after the coating removal. Small spots of white coating remained, but few were as large as the one-inch-diameter spots that were considered acceptable.

The edges of adhering coating that was not removed, for example, at sites of adhesion loss or of chipping by tire chains, were feathered in with hand-held disk grinders. The surface of the coating was then abraded with the scarifier, using abrasive tipped brushes rather than the drum with cutting wheels. The floor was again washed with detergent and bare concrete areas were acid etched. After rinsing, the floor was allowed to dry until all visible water had evaporated.

Thin-Film Coating Systems With Alumina

All bare concrete areas were primed or spot primed with a water dispersible epoxy coating. All areas, including old coating and newly primed areas, were then coated again with the same primer.

There was only one area where problems were encountered in the recoating of the existent old coating. This was in the southern two columns of squares in Bay 6, where the old coating was lifted off by the primer. A contributory reason is likely to have been the fact that the old coating on Bay 6 was not as chemically resistant as the other old coatings in Hangar 5, as evidenced by limited resistance to Skydrol. It was not evident why there was a problem on only this part of the bay. The old, and now partly blistered, coating on these two columns of squares was removed completely and the primer was reapplied.

There were no problems in the application of the CRU coatings or in the even broadcasting of the alumina with a seeder. With each dipping of the 18-inch rollers about one quarter of a 12-foot square was covered in a back and forth motion.

The finished surfaces of Systems 4N and 6N are shown in Figures 3 and 4. These views, as well as those of the other systems, were at the centers of the areas measured for slip resistance. All photographed floor areas were illuminated at 45 degrees above the floor to bring out the textures and all are shown in actual size.

Thin-Film Coating Systems With Polypropylene

The application method was changed slightly for the application of the CRU coating with premixed polypropylene. There was no problem in mixing the grit and keeping it from floating to the top. But the grit tended to be deposited more heavily at the point of first contact of the roller, and a little more force was required to pull the roller across the floor.

The tendency for uneven grit deposit was more evident for the larger spherical pigment of 200-μm average diameter than for the smaller popcorn-shaped pigment of 150-μm average diameter. Acceptably uniform grit distribution was possible using a 1/2-inch mohair roller with shorter strokes and less coverage with each dipping of the roller. Even appearance was easier to achieve with 2 pounds per gallon, rather than 1 pound per gallon, of the larger poly-propylene grit.

The finished surfaces of Systems 1N and 2N are shown in Figures 5 and 6.

Thick-Film Coating Systems

To produce a smooth, level base for the remainder of the coating system, the primer used for the thick-film systems was a thin coat of 100% solids self-leveling epoxy coating, rather than the water-dispersible epoxy used for the thin-film systems. It was poured on the floor, moved back and forth with a squeegee, freed of excess coating with the squeegee, and back-rolled with a 3/8-inch-nap roller. An amine bloom resulted, which may have been caused by failure to wait for the completion of the required 10-minute induction period prior to the application of the coating. The amine bloom was removed by washing with methylethyl ketone (MEK).

The intermediate coat was the same 100% solids self-leveling epoxy coating. For System 3S, it was applied by pouring out the calculated amount of coating required, spreading with a squeegee, and back-rolling with a 3/8-inch-nap roller. The measured wet-film thickness varied from about 6 mils to over 20 mils. After some experience, the thickness could be estimated by the appearance of the surface. The thinner areas were transparent and dark, the thicker areas had more creamy appearances. For System 3N, the self-leveling epoxy was thinned 10% with MEK to reduce the viscosity, and this provided a more even wet film thickness, ranging from about 8 to 14 mils.

The Grit No. 24 alumina was evenly applied with a seeder into the wet intermediate coat. After the coating dried, it was noted that the alumina barely protruded through the surface where the intermediate coat was more than about 14 mils thick. At these sites, two CRU topcoats would have produced very slippery floors. Therefore, these areas of System 3S and the back row of System 3N were overcoated with an additional CRU coat into which 3 lb per 1000 sq ft of Grit No. 36 alumina were broadcast. These areas, which are delineated in Figure 2, were not considered part of the field test. The thick-film systems were completed by the application of two CRU topcoats.

The finished surface of System 3N is shown in Figure 7.

Organic Toppings

After the removal of old coating, the front portion of Bay 3 was primed with a preliminary protective coat of the same water-dispersible epoxy primer that was used for the thin-film systems. Two months later, the area was cleaned and abraded, and an additional preliminary coat of a solvent-based epoxy primer was applied to assure good adhesion of the organic topping systems. This area was divided into six smaller areas for the application of Systems 3A to 3F, as described in Table 3 and shown in Figure 2.

The 60-mil epoxy slurry coat at the front two rows of the bay, for Systems 3A to 3C, was applied with a 1/4-inch V-notched trowel and was back-rolled. The 16-mil slurry coat at the third and fourth row, for Systems 3D to 3F, was applied with a trowel having small U-notches, partly worn down, that applied about 16 to 18 mils of coating when held at a low angle. The three types of grit used were applied in excess until they were no longer wetted. After overnight curing, the excess grit was swept off. The seal coat was then applied by squeegee in two passes. The first pass displaced considerable air, which produced a foam that dissipated rapidly. The second pass was applied with sufficient pressure to remove any excess coating. After overnight curing, two CRU topcoats were applied.

The thickness of the finished organic toppings that began with the 60-mil slurry coat was approximately 1/8 inch. The thickness obtained with the 16-mil slurry coat was approximately 1/16 inch. The surface of System 3E is shown in Figure 8.

Blisters had developed in the toppings along the concrete joints in June 1989, and the toppings were repaired in November 1989. About a foot of topping, plus any additional loose topping, was removed on both sides of the joints. The concrete substrate was cleaned, and a new topping filled with sand was applied. After the topping cured, spaces were sawn out over the joints, and these spaces were filled with joint sealant.

Rolled-On Epoxy Coating System

The rolled-on epoxy system was applied directly to the bare concrete floor from which the old coating had been removed. The mixed coating was poured on the floor and a short bristle nylon applicator was used to spread the coating and achieve a wavy surface. The first coat was rolled east-west and was applied at 100 sq ft per gal for a calculated wet film thickness of 16 mils, which should provide an average dry film thickness of about 10.6 mils for the 66% by volume solids coating. A second coat was applied the following day. It was rolled north-south at 58 sq ft per gal, which should provide an average dry film thickness of about 18.2 mils, or a total average thickness of about 29 mils.

The application of yellow striping coating was deferred until the sixth day because the epoxy coating hardened very slowly. The striping coating was applied to all other coating systems the day after the application of the final CRU coat. The finished surface of System 4A is shown in Figure 9.

FIELD TEST RESULTS

The coating systems at NAS Brunswick were applied in June 1988, except for the organic toppings which were applied in August 1988. The field test results for these systems are based on slip resistance and reflectance measurements made in October 1988 and on a visual inspection made in August 1989.

There was no significant difference in reflectance between the coating systems with CRU topcoats. The average 45-degree/0-degree reflectance of the thin-film and thick-film systems was 91, with individual readings varying by no more than two units. The average reflectance of the organic toppings, which had a different CRU topcoat, was 93. The rolled-on epoxy coating had an average reflectance of 66.

Slip resistances of the coating systems were measured with three instruments under a variety of conditions. The Horizontal Pull Slipmeter was used on clean, dry test surfaces. This instrument is shown in Figure 10 and described in American Society for Testing and Materials (ASTM) Method F 609. It is the most readily available standard instrument, but it is intended only for smooth surfaces, rather than the textured reflective floor coatings. It measures the static coefficient of friction.

The British Pendulum Tester was used on test surfaces wetted with water or with hydraulic fluid. It is shown in Figure 11 and described in ASTM Method E 303. It is intended for pavement surfaces, and appears suitable for floor coatings. It measures dynamic friction, but it does not provide a coefficient of friction. It measures the slip resistance of a small area, about 3-in. by 5-in., rather than the average of a larger area; it is a research instrument that is not suitable for routine field tests.

The NCEL Slipmeter also was used on test surfaces wetted with water or with hydraulic fluid. This slipmeter was developed as a prototype of a field instrument for measuring dynamic coefficient of friction (Ref 1). It is shown with a sled weighing 10 kg, in Figure 12. A 10-lb sled with three rubber feet was used for the hangar floor measurements. It is shown with associated instrumentation in Figure 13. This sled was pulled across the test surfaces at three different speeds with a 10-lb digital force gauge. The resultant reading along a traveled path was plotted on a strip-chart recorder as the coefficient of friction.

The rubber used on the platen of the pendulum of the British Pendulum Tester and for the feet of the sled of the NCEL Slipmeter was the carboxylated nitrile rubber that is used on Navy safety shoes. The three feet of the sled were beveled at the front to prevent hang-up on protrusions. Measurements were made with three short feet having 1-cm by 1-cm contact surfaces and also with three long feet having 1-cm by 3.3-cm contact surfaces. The sled was pulled at speeds of 1250, 2500, and 5000 cm per min (about 0.5, 1, and 2 mph).

For each coating system, areas were chosen for measurements that were reasonably accessible during normal hangar operations. The floor plan of the bays is shown in Figure 2, which also depicts the layout of the eight coating systems in Bay 3. (The shaded areas in this bay are not part of the field test because of modifications that had to be made in the application of the coating systems at these areas.) The systems labeled S and N were on opposite sides of the center line and the areas chosen for measurement were in Blocks 3G and 7G of each bay, as depicted in Figure 2 (except that for Systems 2S and 2N they were in Blocks 3F and 7F). For Systems 3D, 3E, and 3F, the areas were in Blocks 2C, 5C, and 8C, respectively, and for System 4A, the areas were in Block 8D.

The blocks chosen for measurement were washed with detergent, rinsed, squeegied, and allowed to dry. On representative and uniform surfaces of the blocks, 4-ft strips running west to east were chosen for the measurements. At the centers of the dry cleaned strips, reflectance measurements were made and also slip resistance measurements with the Horizontal Pull Slipmeter. The strips were wetted with water for British Pendulum measurements at the center of the strip and for NCEL Slipmeter measurements along the strip. After drying, the strips were wetted with hydraulic fluid (MIL-H-83282) for oily measurements with the same two instruments.

The slip resistances that were obtained are listed in Table 5. The slip index values obtained with the Horizontal Pull Slipmeter are the averages of five determinations. The British Pendulum numbers are also the averages of five determinations. The coefficients of friction obtained with the NCEL Slipmeter each are the average values of two recorder traces.

The slip resistances on oily surfaces were considered to be the most significant measurements because slipping typically occurs on oily floors, rather than on clean, wet floors. The dynamic coefficient of friction probably relates more closely to the ability of the hangar floors to resist slipping than does the static coefficient of friction.

Static coefficient of friction measurements are increased by intimate contact established between the surfaces before the measurements are taken. The presence of oil between the surfaces increases this contact much more than does the presence of water. The result is higher static coefficients of friction for the oily panels than for the wet panels. This apparent anomaly gives further support to the choice of dynamic, rather than static, measurements for determining the safety of floors (Ref 1).

The oily dynamic slip resistance measurements for the various coating systems, obtained with the British Pendulum Tester and with the NCEL Slipmeter using short and long feet at 1250 cm per min, are listed in Table 6. These slip resistance values were extracted from Table 5.

The following are significant field test results for the various types of coating systems:

Thin-Film Coating Systems With Alumina

The six thin-film systems with alumina (Systems 4S to 6N) all had good slip resistance. As expected, larger grit or larger amounts of grit provided increased slip resistance, whereas additional topcoats provided reduced slip resistance. However, the differences were not as great as might have been expected. Personnel using the hangar bays coated with these systems generally did not observe any differences in slip resistance.

User response to the above coating systems was obtained from questionnaires circulated by Patrol Squadron 23 at NAS Brunswick in August 1989. The questions concerned differences in slipperiness, reasons for the slipperiness, slips and resulting injuries, and suggestions for improvements. An abbreviated summary of significant entries in 32 completed questionnaires is presented in Table 7.

The differentiation between the coatings in the north and south sections of the hangar bays did not appear to be clear to the questionnaire respondents. Some respondents perceived Bay 6 to be the most slippery, which may have been partly because aircraft washing is performed primarily in this bay. It would have been desirable to determine whether aircraft washing would have given an appreciably less slippery floor in Bay 4. However, Bay 4 was not equipped with the safety harnesses required for aircraft washing and thus no comparison was possible. The survey does indicate that aircraft detergent may pose as great a slip hazard as oil on the floors. The detergent is an unavoidable hazard during washing operations, whereas the oil can be removed.

A brief opportunity to inspect the above floors about one year after application indicated relatively little loss of grit as compared to the loss of grit from the more typical older system applied in a prior field test at the same location. This typical older system contained the larger grit no. 30 alumina and only one topcoat after the application of grit. Even though the usage of the floor may not have been identical, it appears that all the thin-film systems in the current test are better than the older system and should provide longer performance.

Thin-Film Coating Systems With Polypropylene

The four thin-film systems with polypropylene (Systems 1S to 2N) provide a smoother and more pleasant surface than the rougher and more aggressive surfaces of the systems with alumina. As perceived by air station personnel, the two systems with the 200-μm polypropylene grit had acceptable slip resistance. The two systems with the smaller 150-μm polypropylene grit were considered to be undesirably slippery.

The systems with polypropylene all had lower measured slip resistances than the systems with alumina. The two systems with the 150-μm grit were appreciably more slippery than the two systems with the larger 200-μm grit as measured with the British Pendulum Tester and with the NCEL Slipmeter at 5000 cm per min, as shown in Table 5. This differentiation was not evident at 1250 cm per min. The different amounts of grit contained in the systems had little effect on the slip resistance.

Thick-Film Coating Systems

The thick-film systems provided good slip resistance, as perceived by air station personnel. Subjective comparisons with the thin-film systems containing alumina were difficult because the two types of systems were used by different squadrons. The squadron washing aircraft on the thick-film systems at the back of Bay 3 reported fewer slipping problems than the squadron washing aircraft on the thin-film system in Bay 6. The squadron in Bay 3 apparently preferred the thick-film systems to the organic toppings at the front of the bay.

The measured slip resistance of the thick-film system with the larger amount of grit, System 3N, was essentially the same as that of the most slip resistant thin-film system, System 4N.

The thick-film systems were thin enough to crack along all the floor joints, as did the thin-film systems. This avoided the problem with water transpiration that is described below for the organic toppings.

Organic Toppings

The organic toppings appeared to be very serviceable coatings with good slip resistances. The toppings with alumina had measured slip resistances that were appreciably better than those of the toppings with sand. The organic toppings were much more resistant to damage by tires with snow chains than the thin-film coating systems.

The organic toppings applied at NAS Brunswick gave good service for approximately 10 months, from August to about June. Apparently at that time and rather suddenly, blisters appeared at most of the joints. These blisters were up to about 6 inches wide and up to several feet long. Many of the blisters were crushed in traffic, leaving patches of uncoated concrete, as illustrated in Figure 14. The blisters occurred on either side of the joint, and sometimes alternated, but were not on both sides at the same time. The only joints that did not have blisters were joints where the topping had cracked or joints that were close to a trench.

The blisters appear to have been caused by increased moisture transmission as the weather warmed during the spring. A plausible explanation is that the increased water vapor transmission from the warming of the moist concrete was greatest at the joints, where the concrete was thinnest. The vapor pressure caused delamination of the coating at one side of the joint, which relieved the pressure and left no cause for blistering at the other side of the joint. Where the topping had previously cracked over the joint, or where the joint was close enough to a trench to allow the water vapor pressure to dissipate, no blistering at the joint occurred. Only two small blisters developed away from the joints on the 36 coated slabs.

No blistering at the joints was observed for the thin-film or thick-film coating systems. Blisters may have been prevented by the cracks along the joints that developed in all these systems, as illustrated in Figure 15.

Experiences with organic toppings at other field sites had variable results. At an indoor location at NAD Pensacola, an organic topping with sand in an epoxy matrix and without CRU topcoats gave good performance for more than 7 years. In a maintenance hangar at NAS Jacksonville, a similar topping but with CRU topcoats was reported to have given good performance during the first year.

In a maintenance hangar at NAS Norfolk, toppings intended to be similar to those at NAS Brunswick provided major problems that appeared to be related to the nature of the substrate. Rough concrete surfaces caused the seal coat to flood the grit in depressed areas and to flow away from the grit at raised areas. This caused the finished toppings to be very slippery or very rough at these respective areas. Extensive blistering occurred in many areas, followed by crushing and loss of the topping. This may have been caused by excessive water vapor transmission through the concrete. Extensive pinholes developed, apparently because of off-gassing of the concrete during the application and curing of the topping. These pinholes were surrounded by half-inch-diameter craters that developed when bubbles were blown during the application of the CRU topcoat and later crushed, as shown in Figure 16. An effect of these pinholes was that wash water was sucked into the porous concrete in the evening, and as the temperature increased the next morning, dirty brown water exuded onto the white floor.

Rolled-On Epoxy Coating System

The rolled-on epoxy system had a less white appearance than the other coating systems and was more difficult to keep clean. The average reflectance of the clean coating was 66, whereas that of the systems with CRU topcoats was more than 90. This particular system required several days for curing. It contained considerable entrained air, as shown by visual observation of a cross section of the coating that had been applied to a test panel assembly.

The slip resistance of the rolled-on epoxy coating system was intended to be provided primarily by the wavy texture produced in the application of the coating by roller. Because this wavy texture varied considerably, the slip resistance also varied. In an eight-foot path perpendicular to the wavy texture, which was chosen as representative of the system, three oily slip resistance measurements with the British Pendulum Tester gave values of 26, 36, and 51. (No comparable measurements were made for the other systems, but recorder traces of the measurements with the NCEL Slipmeter showed a greater variation for the rolled-on epoxy system.)

Rolled-on epoxy coating systems, as represented by the coating tested, do not appear desirable for hangar floors. This coating does not provide any net advantage over the thin-film systems. Its reflectance is considerably lower than that of the coating systems with CRU topcoats. It is more difficult to clean, and its slip resistance is strongly affected by the method of application. It would not be expected to lose its grit, but it may have a greater tendency to yellow.

COATING SYSTEM DESIGN REQUIREMENTS

Based on the NAS Brunswick field test results to date and on other field experiences, the best coating system design currently available for general Navy use is a thin-film coating system with CRU topcoats. Thick-film coating systems appear to be an improvement over the thin-film systems and should provide longer service life, but the required expertise for their commercial application is not available. Organic toppings should provide still longer service if properly applied. But they have caused problems where improperly applied or applied in the wrong environments.

Concrete Substrates

The concrete substrate is not part of the coating system design. However, the nature of the substrate and the manner of application of the coating system may be the overriding factors that affect the performance of the coating system. High performance coatings generally have poor adhesion to surfaces that are oily or otherwise not clean. The surface must be dry for the application of solvent-based coatings. For application of water-based epoxy primers, the absence of visible moisture may be adequate.

Smooth concrete substrates will produce the most functional coated floors and the best slip resistance for a given system design. Rough surfaces may produce rapid wear and grit loss at raised areas. A troweled finish is better than a floated or broomed surface. A rough surface can be smoothed by application of a self-leveling epoxy coating.

The concrete should have a low rate of water vapor transmission. Excessive water vapor transmission often causes blistering of impervious epoxy floor coatings and floor tile adhesives. The water transmission of concrete on grade is affected by the porosity of the concrete, but usually it will be too high if the concrete is in direct contact with water.

Concrete that is very weak may have cohesion that is less than the adhesion of the coating. The coating may then be lost with adhering concrete or sand under the primer, and it will appear to have lost adhesion. Concrete can be weakened by excessive acid etching that removes the cement binder near the surface.

Application of coatings to concrete that is porous enough to produce off-gassing under conditions of rising temperature may lead to holidays, or holes, in the coating system. These holidays may not be sealed by subsequent coats if there is renewed release of vapors at the same sites. The above substrates may be coated satisfactorily by applying a primer, or a series of coatings capable of sealing the surface, in the afternoon after the floor temperature ceases to rise, provided the concrete has low water vapor transmission.

In recoating operations, portions of old coatings that are solvent resistant and in good conditions, except for loss of grit, need not be removed. But the surfaces must be abraded to allow good adhesion. For mechanical removal of thin-film coatings, wet grinding with drum sanders or large buffers can be used. Sacrifiers can easily damage the concrete surface when not used by experts. Centrifugal shot blasting of resilient coatings can leave patches of coating surrounded by gouged concrete.

Thin-Film Coating Systems

The reflective coating system recommended for coating or recoating of Navy maintenance hangar decks subject to general use is a thin-film reflective chemically resistant urethane (CRU) floor coating system (about 10 mils thick) consisting of a primer, a 2.5-mil CRU topcoat into which grit no. 46 alumina is uniformly broadcast at 6 lb per 1000 sq ft, and two additional 2.5-mil coats of CRU topcoat. (This system has smaller grit, twice the amount of grit, and an additional CRU topcoat compared to systems typically specified in the past.) The primer used can be a water-based epoxy primer as used in this field test, but a solvent-based epoxy or epoxy urethane, or a properly applied moisture cured urethane, as used in other field tests, can also be satisfactory. The CRU topcoat is a two-component system.

The thin-film coating system can be modified by using grit no. 36 alumina for greater slip resistance, or by using grit no. 54 alumina for better cleanability. However, the finer grit no. 54 is not recommended in areas where there is extensive washing of aircraft. Where a less abrasive surface is desirable, polypropylene grit can be used; in this case, a pigment of 200-μm average diameter premixed at 1.5 lb per gal is recommended.

The above coating systems should provide service that is significantly improved over that provided in the past by coating systems with larger grit and thinner topcoats. However rough use of the floors should still be avoided to prevent excessive loss of grit.

Thick-Film Coating Systems

A thick-film coating system (about 20 mils thick), would be proposed for general use if the better performance of such a system is borne out in future monitoring of the field test, and if the expertise required for its commercial application is developed. This system would consist of a primer, a 12-mil intermediate epoxy coat into which grit no. 24 alumina is uniformly broadcast at 12 lb per 1000 sq ft, and two additional 2.5-mil coats of CRU topcoat.

There is no accepted commercial method for accurately applying a 12-mil, 100% solids epoxy intermediate coat. It should be possible to apply a desired film thickness by selection of the proper V- notch trowel and the angle at which it is held in the coating application, provided the substrate is smooth and nonabrasive. For a V-notched trowel, the average clearance is half the depth of the notch. This is about 45 mils for a 3/32-inch notch and about 30 mils for a 1/16-inch notch. Held at 45, 30, and 15 degrees, the average clearances are 32, 23, and 12 mils, and 21, 15, and 8 mils, respectively. But the applied coating film will differ depending on viscosity and other factors.

Laboratory experiments with a V-notched trowel on a smooth glass plate, demonstrated that the application of an even coating film should be possible commercially. A 3/32-inch V-notched trowel was used because it was the smallest one commercially available. Holding this trowel at angles of 45, 30, and 15 degrees gave 21-mil, 17-mil, and 16-mil films, respectively. With a 1/16-inch V-notched trowel, the clearance would be one third less, and on a smooth nonabrasive surface, it should thus be possible to prepare a film 12 to 14 mils thick. The smooth surface could be obtained by filling the concrete with a 100% solids epoxy primer.

Organic Toppings

Organic toppings are not recommended for general use in Navy aircraft maintenance hangars. Such coating systems can provide excellent service when properly applied to smooth concrete surfaces. However, when applied to concrete on grade, blistering and adhesion losses can be caused by excessive moisture migration, and we do not know the moisture limitations for the use of these coating systems. Joints in concrete on grade should not remain covered by toppings; the toppings should be cut out over the joints and filled with joint sealant.

CONCLUSIONS

1. Conclusions can be drawn only as based on the initial performance of the reflective coating systems, because most of the reported data was obtained shortly after the coatings were applied. Conclusions about the service life will have to await further field test monitoring.

2. Considerable skill, beyond that possessed by the typical painting contractor, is required for proper application of these coating systems. The following conclusions apply to properly applied systems.

3. Smooth substrates of low porosity are required for optimum performance of these coating systems. The following conclusions apply to systems on such substrates.

4. Thin-film reflective chemically resistant urethane (CRU) floor coating systems (about 10 mils thick) with acceptable slip resistances can be obtained with grit no. 46 or 54 alumina, rather than the larger grit no. 30 or 36 alumina that more typically has been used.

5. The same coating systems can be obtained with acceptable slip resistances using two CRU coats after broadcasting of the alumina, rather than the single additional coat more typically used.

6. Either of the above changes is expected to increase the service life of the initially applied coating system but to reduce the slip resistance. However, even with reduced grit size and increased topcoat coverage acceptable slip resistance can be obtained.

7. When a second CRU topcoat is used after broadcasting the alumina, doubling the amount of alumina previously recommended (from 3 lb to 6 lb per 1000 sq ft) is desirable for improved slip resistance.

8. Replacement of the alumina grit by polypropylene grit allows the grit to be premixed in the coating before application and can produce a less abrasive surface with acceptable slip resistance.

9. A thick-film coating system (about 20 mils thick), with a 12-mil intermediate epoxy coat and grit no. 24 alumina, can provide good slip resistance and is expected to have a much longer service life than the typical thin-film reflective CRU coatings (at a cost increase of about 25%). But the required expertise for its commercial application is not available.

10. A practical application method for thick-film coating systems could easily be developed, as judged from laboratory experiments.

11. Organic toppings (about 1/16 to 1/8 inch thick) can also provide good slip resistance and are expected to provide much longer service than the thin-film coating systems if properly applied (at a cost increase of about 75% to 175%). But the organic toppings have caused problems where improperly applied, or applied to concrete subject to high moisture transmission, and require costly removal procedures before replacement or recoating.

RECOMMENDATIONS

1. The reflective coating system recommended for recoating of Navy maintenance hangar decks subject to general use is a thin-film reflective chemically resistant urethane (CRU) floor coating system (about 10 mils thick) consisting of a primer, a 2.5-mil CRU topcoat into which grit no. 46 alumina is uniformly broadcast at 6 lb per 1000 sq ft, and two additional 2.5-mil coats of CRU topcoat. (Note: Current NAVFAC guidance, contained in Design Policy Letter DPL-0005 of 27 Jun 88, discourages the use of reflective coatings in new construction because of potential maintenance problems.)

2. Where desirable, the above system should be modified by using grit no. 36 alumina for greater slip resistance, by using grit no. 54 alumina for better cleanability, or by using premixed polypropylene grit for a less abrasive surface.

3. The field test at NAS Brunswick should be monitored annually to determine longer term performance of the coating systems.

4. A method should be developed for the practical application of thick-film coating systems. Such systems, about 20 mils thick, are likely to provide better performance than the thin-film systems and it appears that a practical application method could easily be developed.

5. Research should be performed to overcome problems caused by very porous or rough concrete. Such problems apply not only to floors with reflective coatings, but also to floors with epoxy coatings or other high performance coatings.

REFERENCE

1. Naval Civil Engineering Laboratory. Technical Report R-932: Slipmeter for floor coatings, by Peter J. Hearst. Port Hueneme, CA, Apr 1991.

Table 1. Grit Size Requirements
[Adapted from ANSI B74.12-1976, Table 2]

Sieve No.	Opening (Mils)	Retention Requirements for Various Grit Sizes				
		No. 54	No. 46	No. 36	No. 30	No. 24
16	47					100% passes
18	40				100% passes	*
20	33			100% passes	*	max 25% ret
25	28			*	max 25% ret	min 45% ret
25&30						min 65% ret
30	23		100% passes	max 25% ret	min 45% ret	*
30&35					min 65% ret	
35	20	100% passes	*	min 45% ret	*	<3% passes
35&40				min 65% ret		
40	17	*	max 30% ret	*	<3% passes	
45	14	max 30% ret	min 40% ret	<3% passes		
45&50			min 65% ret			
50	12	min 40% ret	*			
50&60		min 65% ret				
60	10	*	<3% passes			
70	8	<3% passes				
65% range**		10 to 14	12 to 17	17 to 23	20 to 28	23 to 33
97% range***		8 to 20	10 to 23	14 to 33	17 to 40	20 to 47

* No requirement specifically for this sieve.
** Approximate size range of at least 65% of the grit, in mils.
*** Approximate size range of at least 97% of the grit, in mils.

Table 2. Thin-Film Coating Systems Applied at NAS Brunswick*

System 1S		
	Coat 2	2.5-mil CRU with premixed 150-μm polypropylene at 0.5 lb/gal
	Coat 3	2.5-mil CRU with premixed 150-μm polypropylene at 0.5 lb/gal
System 1N		
	Coat 2	2.5-mil CRU with premixed 150-μm polypropylene at 0.75 lb/gal
	Coat 3	2.5-mil CRU with premixed 150-μm polypropylene at 0.75 lb/gal
System 2S		
	Coat 2	2.5-mil CRU with premixed 200-μm polypropylene at 1 lb/gal
	Coat 3	2.5-mil CRU (w/o grit)
System 2N		
	Coat 2	2.5-mil CRU with premixed 200-μm polypropylene at 2 lb/gal
	Coat 3	2.5-mil CRU (w/o grit)
System 4S		
	Coat 2	2.5-mil CRU with grit no. 36 alumina, 3 lb/1000 sq ft
	Coat 3	2.5-mil CRU (w/o grit)
	Coat 4	2.5-mil CRU (w/o grit)
System 4N		
	Coat 2	2.5-mil CRU with grit no. 36 alumina, 6 lb/1000 sq ft
	Coat 3	2.5-mil CRU (w/o grit)
	Coat 4	2.5-mil CRU (w/o grit)
System 5S		
	Coat 2	2.5-mil CRU with grit no. 46 alumina, 6 lb/1000 sq ft
	Coat 3	2.5-mil CRU (w/o grit)
	Coat 4	2.5-mil CRU (w/o grit)
System 5N		
	Coat 2	2.5-mil CRU with grit no. 46 alumina, 6 lb/1000 sq ft
	Coat 3	2.5-mil CRU (w/o grit)
System 6S		
	Coat 2	2.5-mil CRU with grit no. 54 alumina, 6 lb/1000 sq ft
	Coat 3	2.5-mil CRU (w/o grit)
System 6N		
	Coat 2	2.5-mil CRU with grit no. 54 alumina, 6 lb/1000 sq ft
	Coat 3	2.5-mil CRU (w/o grit)
	Coat 4	2.5-mil CRU (w/o grit)

*The numbers of the coating systems are the same as the numbers of the hangar bays. S and N refer to the south and north halves of each bay, except that in Bay 4 the front four rows of slabs are coated with a different system. Coat 1 of each system was a water-based epoxy primer. The polypropylene was premixed in the coating before application; the alumina was broadcast into the wet second coat.

Table 3. Thick Coating Systems Applied at NAS Brunswick*

System 3S

Coat 1	Epoxy primer (thin coat of 100% solids self-leveling epoxy)
Coat 2	12-mil self-leveling epoxy with grit no. 24 alumina, 6 lb/1000 sq ft
Coat 3	2.5-mil CRU (w/o grit)
Coat 4	2.5-mil CRU (w/o grit)

System 3N

Coat 1	Epoxy primer (thin coat of 100% solids self-leveling epoxy)
Coat 2	12-mil self-leveling epoxy with grit no. 24 alumina, 12 lb/1000 sq ft
Coat 3	2.5-mil CRU (w/o grit)
Coat 4	2.5-mil CRU (w/o grit)

Toppings in Bay 3:

Preliminary coat of water-based epoxy primer (in June 1988)
Preliminary coat of solvent-based epoxy primer (in Aug 1988)

Coat 1	for 1st and 2nd rows: 60-mil slurry coat proportioned 1-1/4 gal 100% solids epoxy, 3/4 gal silica flour, and 1 gal 20/40-mesh sand, with the following grit added in excess, and excess grit brushed off after curing: System 3A (southern three slabs): 16/30-mesh sand System 3B (central three slabs): grit no. 30 alumina System 3C (northern three slabs): grit no. 24 alumina
Coat 1	for 3rd and 4th rows: 16-mil slurry coat proportioned 1-1/4 gal 100% solids epoxy and 1 gal silica flour, with the following grit added in excess, and excess grit brushd off after curing: System 3D (southern three slabs): 16/30-mesh sand System 3E (central three slabs): grit no. 30 alumina System 3F (northern three slabs): grit no. 24 alumina
Coat 2	Approximately 16-mil 100% solids epoxy seal coat (applied to fill all voids but with excess squeegeed off as much as possible)
Coat 3	2-mil CRU (w/o grit)
Coat 4	2-mil CRU (w/o grit)

System 4A

Coat 1	10-mil textured epoxy with fine alumina grit
Coat 2	20-mil textured epoxy with fine alumina grit

*For Systems 3S and 3N, at the major portions of the south and north halves of Bay 3, the alumina was broadcast into the wet applied coating; for Systems 3A to 3F, at the front four rows of Bay 3, the grit was applied in excess, as described; for System 4A, at the front four rows of Bay 4, the alumina was premixed.

Table 4. Sieve Analyses of Grit Used*

For Thin-Film and Thick-Film Coatings

Sieve No.	#54 Alumina	#46 Alumina	#36 Alumina	#24 Alumina
16				0
20			0	1.7
25			**	60.3
30		0	19.5	33.5
35	Trace	**	64.0	4.5
40	2.6	30.5	15.2	
45	18.9	52.5	1.3	
50	56.3	15.0		
60	19.5	2.0		
70	2.3			
Pan	0.5			

For Organic Toppings

Sieve No.	#30 Alumina	#24 Alumina	16/30 Sand
16	0	0	0
18	0.1	1.8	1.0
20	1.8	34.4	55.4
25	20.2	45.7	34.8
30	53.2	15.7	6.3
35	21.2	1.9	1.5
40	3.4	0.4	0.9
45	0	0	0.1

*The values are percent retained on the sieves indicated.
**This sieve was not used.

Table 5. Slip Resistance Measurements of Hangar Bay Floors*

Ctng Syst	HPS (SI) Dry	BPT (BPN) Water	BPT (BPN) Oil	NCEL Slipmeter (COF)											
				Water						Oil					
				Short Feet			Long Feet			Short Feet			Long Feet		
				1250	2500	5000	1250	2500	5000	1250	2500	5000	1250	2500	5000
1S	6.6	38	22	0.70	0.62	0.55	0.64	0.56	-	0.43	0.39	0.27	0.39	0.36	0.24
1N	6.4	34	25	0.45	0.40	0.36	0.43	0.38	-	0.32	0.29	0.27	0.31	0.27	0.25
2S	5.3	42	31	0.63	0.59	0.56	0.62	0.58	0.51	0.39	0.36	0.33	0.36	0.34	0.31
2N	5.7	42	30	0.66	0.61	0.54	0.61	0.56	0.51	0.33	0.31	0.30	0.34	0.30	0.30
3S	9.3	56	46	0.73	0.70	0.64	0.86	0.83	0.77	0.46	0.39	0.36	0.64	0.61	0.57
3N	9.0	64	58	0.88	0.84	-	1.01	-	-	0.66	0.59	-	0.79	-	-
3D	6.7	47	43	0.52	0.51	0.46	0.69	0.64	0.58	0.40	0.37	0.34	0.48	0.45	0.43
3E	8.1	52	49	0.75	0.72	0.62	0.87	0.83	0.76	0.54	0.48	0.42	0.66	0.61	0.59
3F	7.9	53	49	0.64	0.62	0.56	0.83	0.77	0.72	0.56	0.52	0.46	0.68	0.65	0.60
4A	7.0	42	33	0.66	0.64	0.60	0.72	0.65	0.65	0.50	0.45	0.44	0.45	0.38	0.42
4S	7.7	52	49	0.64	0.61	0.58	0.85	0.80	0.78	0.50	0.46	0.44	0.68	0.64	0.61
4N	9.1	68	60	0.88	0.89	0.82	0.98	0.95	0.92	0.67	0.62	0.59	0.79	0.75	0.74
5S	-	49	46	-	-	-	-	-	-	0.58	0.53	0.50	0.73	0.68	0.67
5N	-	64	57	-	-	-	-	-	-	0.70	0.65	0.62	0.80	0.76	0.75
6S	8.2	54	47	0.76	0.77	0.71	0.61	0.87	0.85	0.50	0.44	0.43	0.66	0.62	0.62
6N	8.5	50	43	0.76	0.72	0.69	0.88	0.85	0.81	0.48	0.45	0.42	0.65	0.62	0.58

*Coating systems are described in Tables 2 and 3. HPS = Horizontal Pull Slipmeter, SI = slip index on dry surface; BPT = British Pendulum Tester, BPN = British Pendulum number on wet and oily surfaces; COF = Coefficient of friction obtained with NCEL Slipmeter on wet and oily surfaces, using a 10-lb sled with 3 short feet (each 1x1 cm) or with 3 long feet (each 1x3.3 cm) at the following three speeds: 1250 cm/min, 2500 cm/min, and 5000 cm/min.

Table 6. Selected Slip Resistances of Oily Coating Systems*

Ctng Syst	Coating System Design						Slip Resistance		
	Coat 1	Grit Type	Amount	Coat 2	Coat 3	Coat 4	BP	Short	Long
				Thin-Film Systems					
1S	CRU	150-μm PP	0.5 lb	Same	--	--	22	0.43	0.39
1N	CRU	150-μm PP	.75 lb	Same	--	--	25	0.32	0.31
2S	CRU	200-μm PP	1.0 lb	CRU	--	--	31	0.39	0.36
2N	CRU	200-μm PP	2.0 lb	CRU	--	--	30	0.33	0.34
4S	CRU	#36 Alumina	3 lb	CRU	CRU	--	49	0.50	0.68
4N	CRU	#36 Alumina	6 lb	CRU	CRU	--	60	0.67	0.79
5N	CRU	#46 Alumina	6 lb	CRU	--	--	57	0.70	0.80
5S	CRU	#46 Alumina	6 lb	CRU	CRU	--	46	0.58	0.73
6S	CRU	#54 Alumina	6 lb	CRU	--	--	47	0.50	0.66
6N	CRU	#54 Alumina	6 lb	CRU	CRU	--	43	0.48	0.65
				Thick-Film Systems					
3S	Epoxy	#24 Alumina	6 lb	CRU	CRU	--	46	0.46	0.64
3N	Epoxy	#24 Alumina	12 lb	CRU	CRU	--	58	0.66	0.79
				Toppings					
3D	Epoxy	16/30 Sand	Excess	Epoxy	CRU	CRU	43	0.40	0.48
3E	Epoxy	#30 Alumina	Excess	Epoxy	CRU	CRU	49	0.54	0.66
3F	Epoxy	#24 Alumina	Excess	Epoxy	CRU	CRU	49	0.56	0.68
				Rolled-On Epoxy					
4A	Textured epoxy w/alumina			Same	--	--	33	0.50	0.45

*Coating system designs are described in more detail in Tables 2 and 3. "PP" designates polypropylene. Coating Systems 3A, 3B, and 3C had surfaces that were indistinguishable from those of the corresponding thinner Systems 3D, 3E, and 3F, and their slip resistances were not measured. Slip Resistance values are British Pendulum numbers and coefficients of friction (obtained with the NCEL Slipmeter with short and long feet at 1250 cm/min) measured on oily surfaces, as reported in Table 5.

Table 7. Hangar Deck Survey Results

A summary of significant responses to a survey on the effect of reflective floor coatings in Bays 4, 5, and 6 of Hangar 5 at NAS Brunswick. The questions concerned differences in slipperiness, with ratings of (1) to (7) for increasing slipperiness; reasons for the slipperiness; slips and resulting injuries; and suggestions for improvements. (No responses for questionnaires 11 to 20, 26, 27, and 38.)

1	Equally slippery; better control of own messes and cleanup
2	Slipped under aircraft with leaking hydraulic fluid
3	Slipped on Bay 7; hydraulic fluid
4	No problems
5	hydraulic fluid; need cleanup
6	No problems
7	Bay 5 slippery with hydr. fluid and oil; slipped at front of Bay 4
8	No problems; stress cleanliness
9	No problems
10	No problems
21	B4 (2), B5 (3), B6 (5); almost slipped in Bay 6; cleaning solution
22	Slipped in Bay 6; cleaning solution
23	B5 (6), B6 (5); slipped after plane wash
24	B4 (3), B5 (3), B6 (6); slipped in Bay 6; cleaning solution
25	Has slipped and gotten bruises; get rid of the white paint
28	No differences; has slipped
29	No problems
30	No differences; paint too slippery
31	Wash bay is slippery; B4 (1), B5 (1), B6 (6); repaint Bay 6
32	No problems
33	No problems
34	2 falls; cleaning solution
35	Everyone clean up their mess
36	B4 (1), B5 (4), B6 (7); slipped in Bay 6; hydraulic fluid & Turco
37	No problems
39	Bay 6 slippery after washing and after "specials/phases"
40	Bay 5 "very bad due to the phases being done there"
41	Bay 6 slippery after wash; has slipped; oil from phase work
42	Plane wash area most slippery
43	Plane wash area most slippery
44	Slippery near props
45	Keep kitty litter available

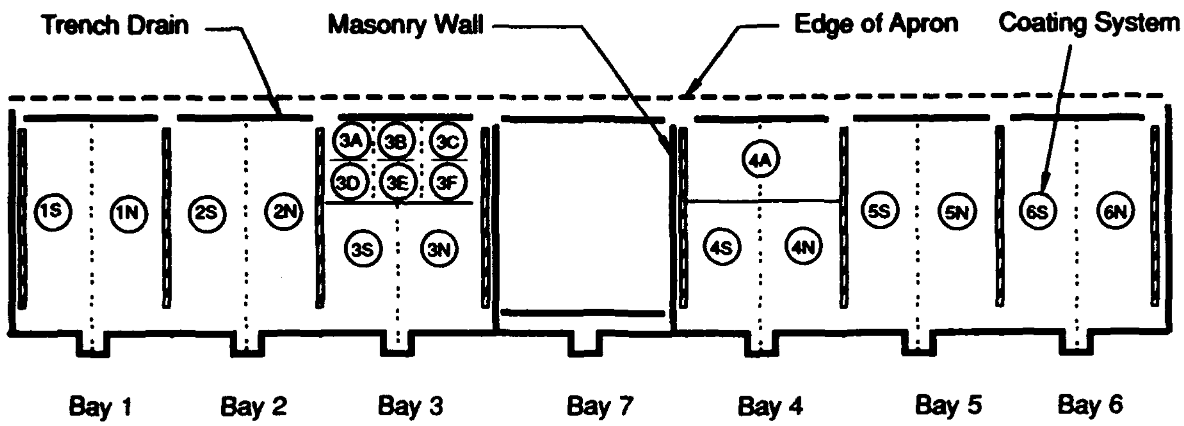

Figure 1. Bays of Hangar 5, NAS Brunswick.

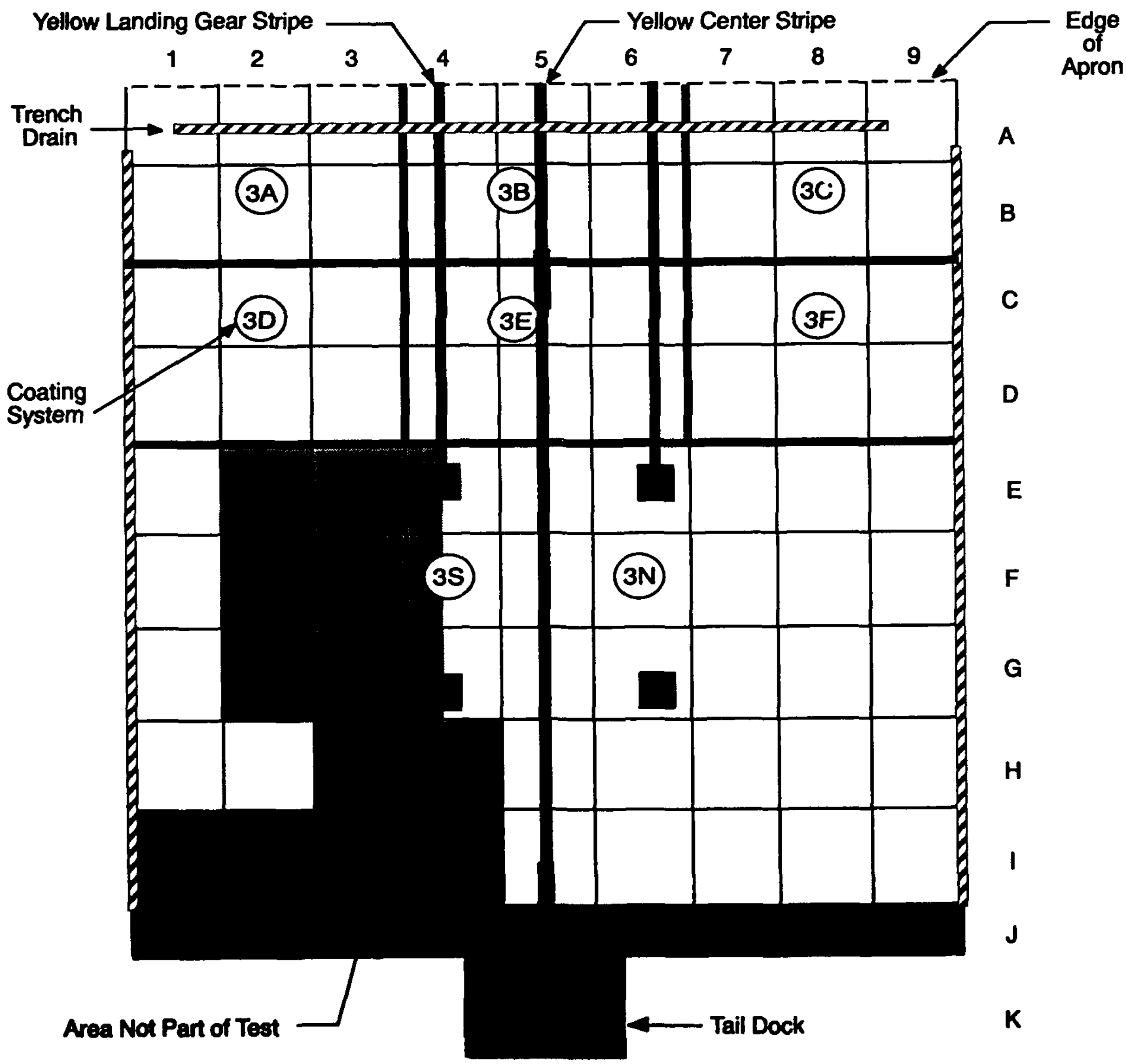

Figure 2. Coating system layout in Bay 3.

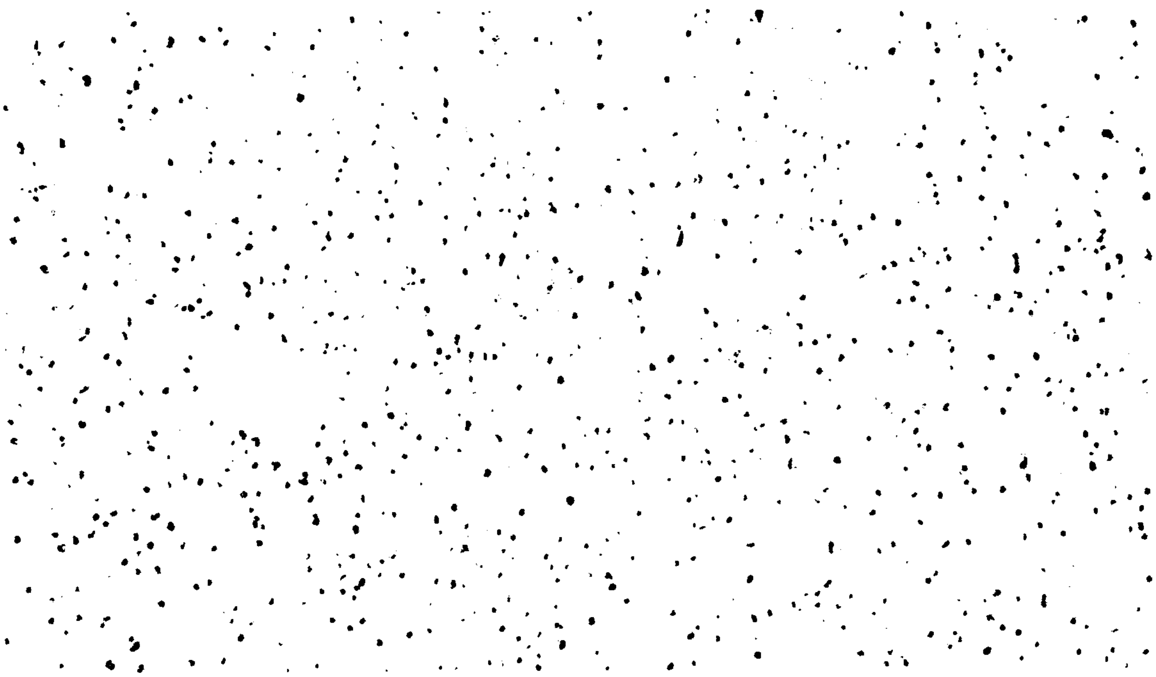

Figure 3. Thin-film System 4N with grit no. 36 alumina.

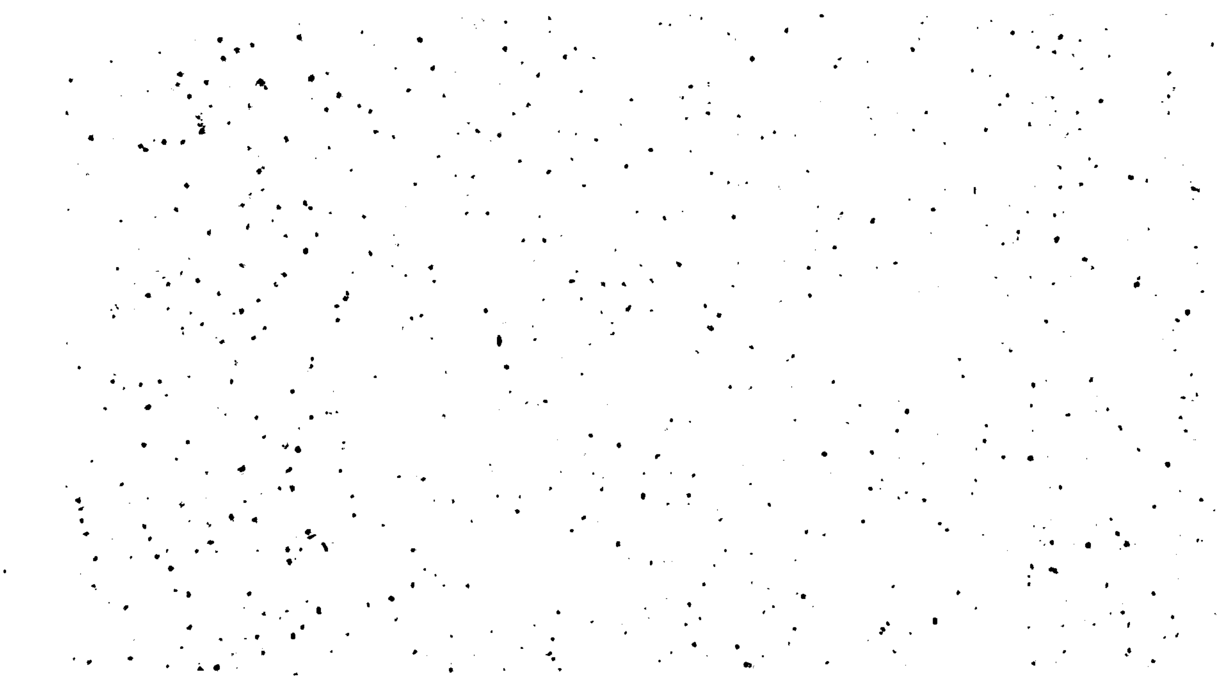

Figure 4. Thin-film System 6N with grit no. 54 alumina.

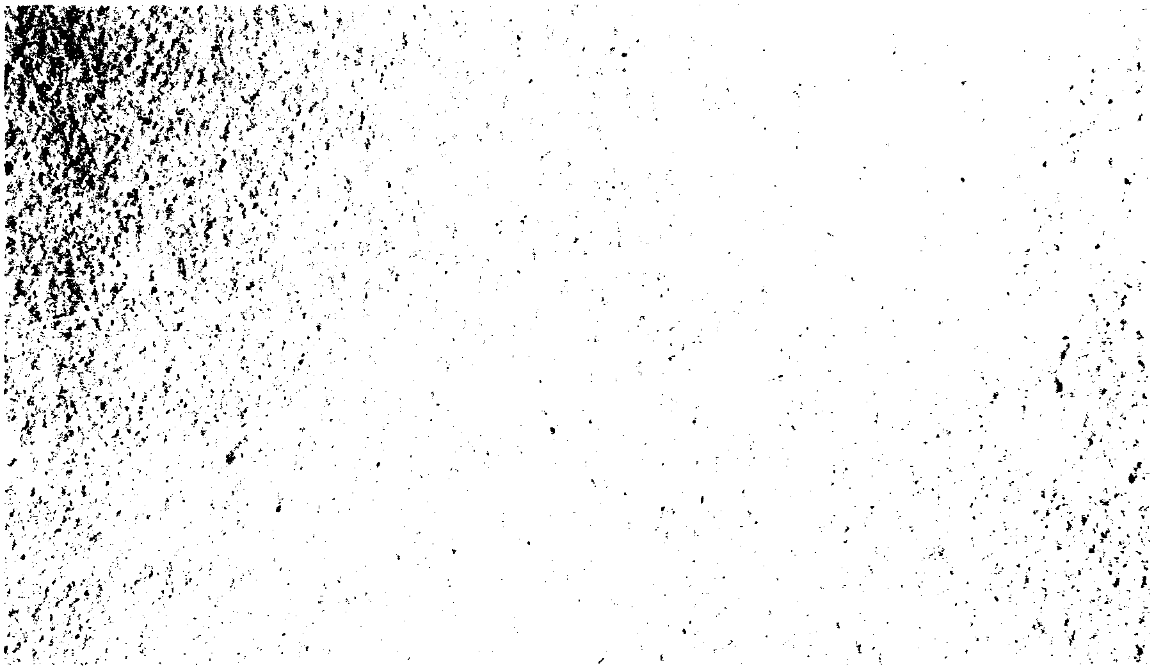

Figure 5. Thin-film System 1N with polypropylene.

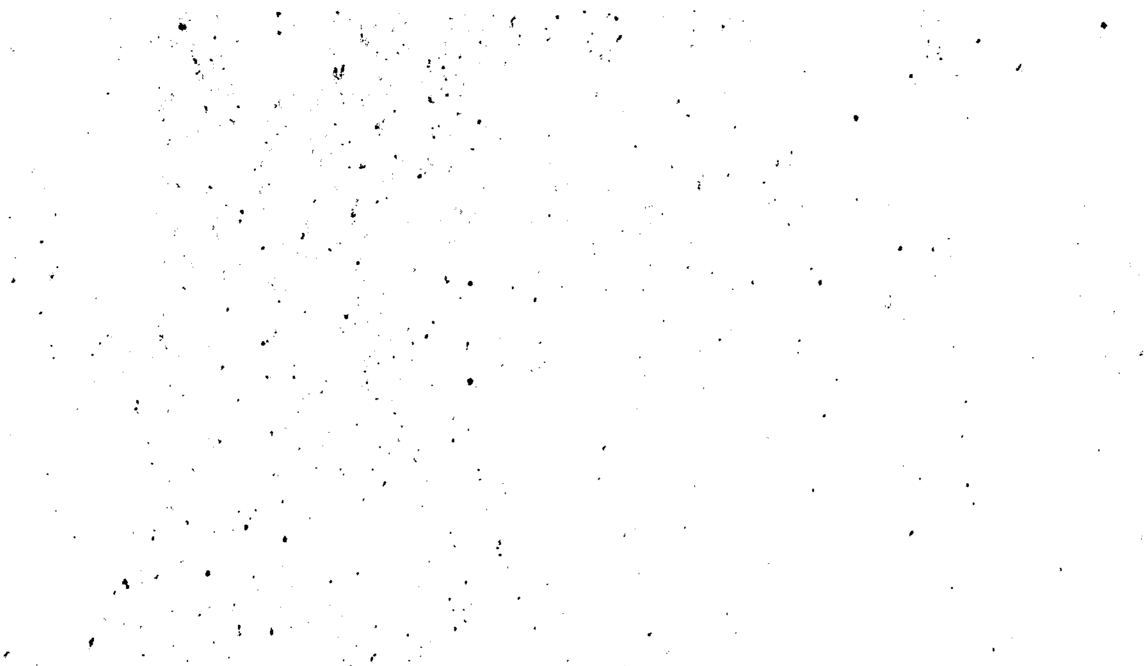

Figure 6. Thin-film System 2N with polypropylene.

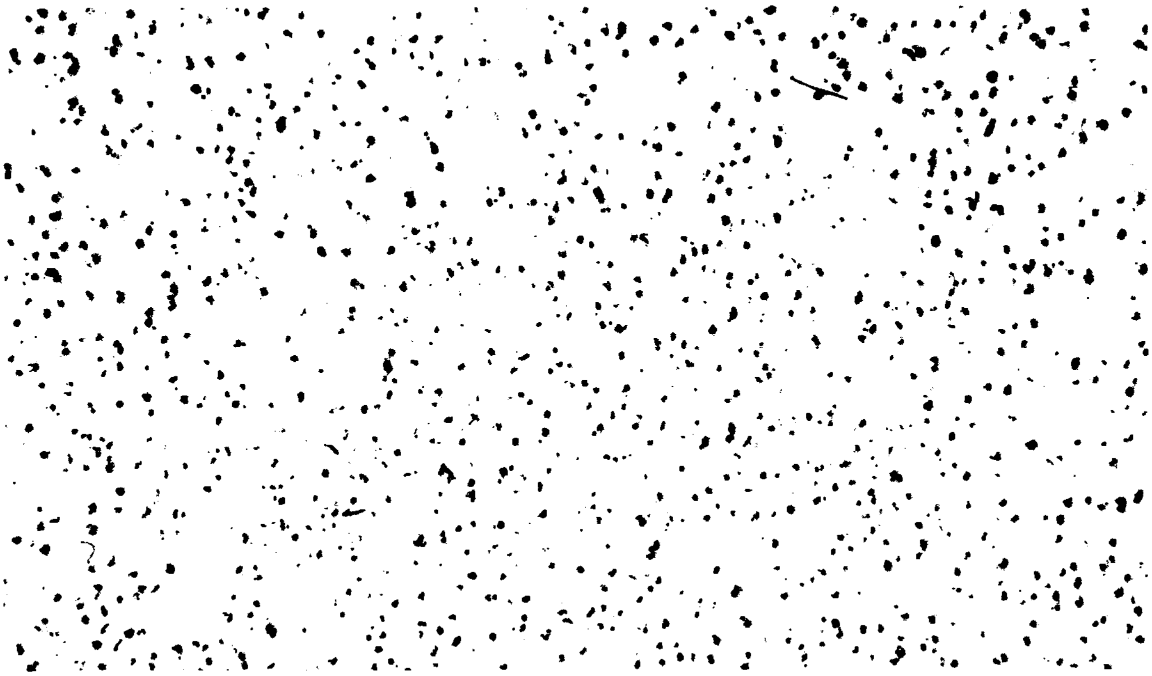

Figure 7. Thick-film System 3N with grit no. 24 alumina.

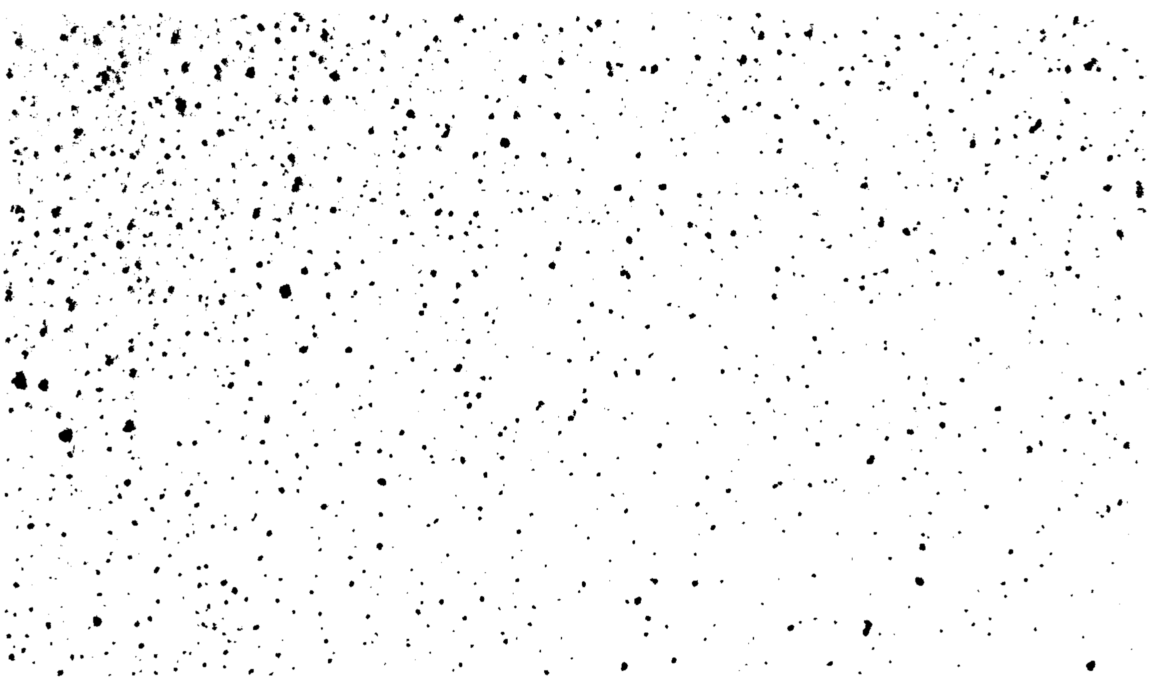

Figure 8. Organic topping System 3E with grit no. 30 alumina.

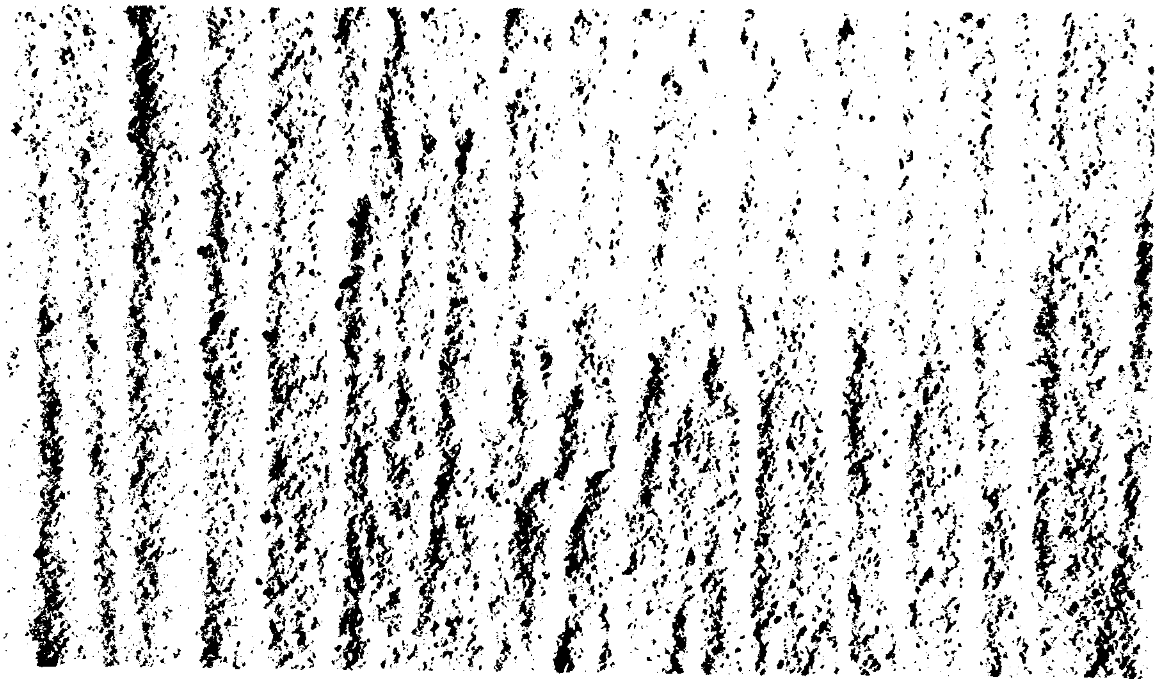

Figure 9. Rolled-on epoxy System 4A.

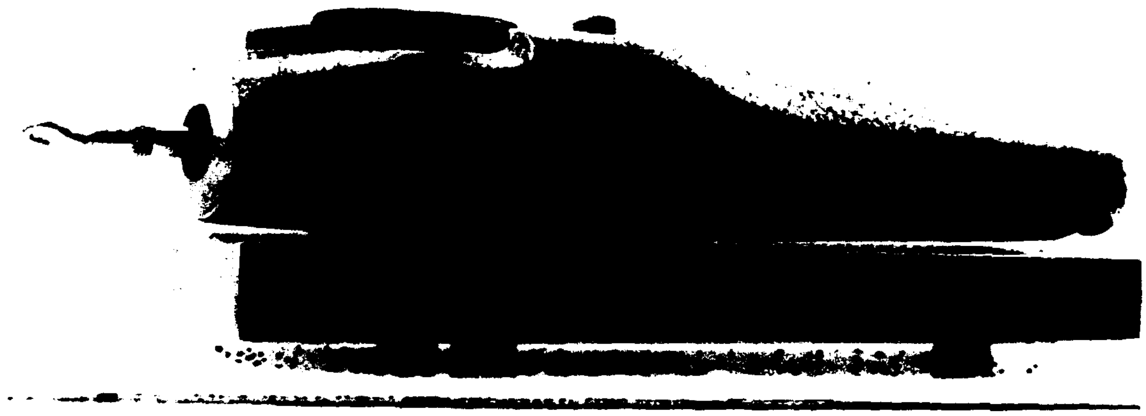

Figure 10. Horizontal Pull Slipmeter.

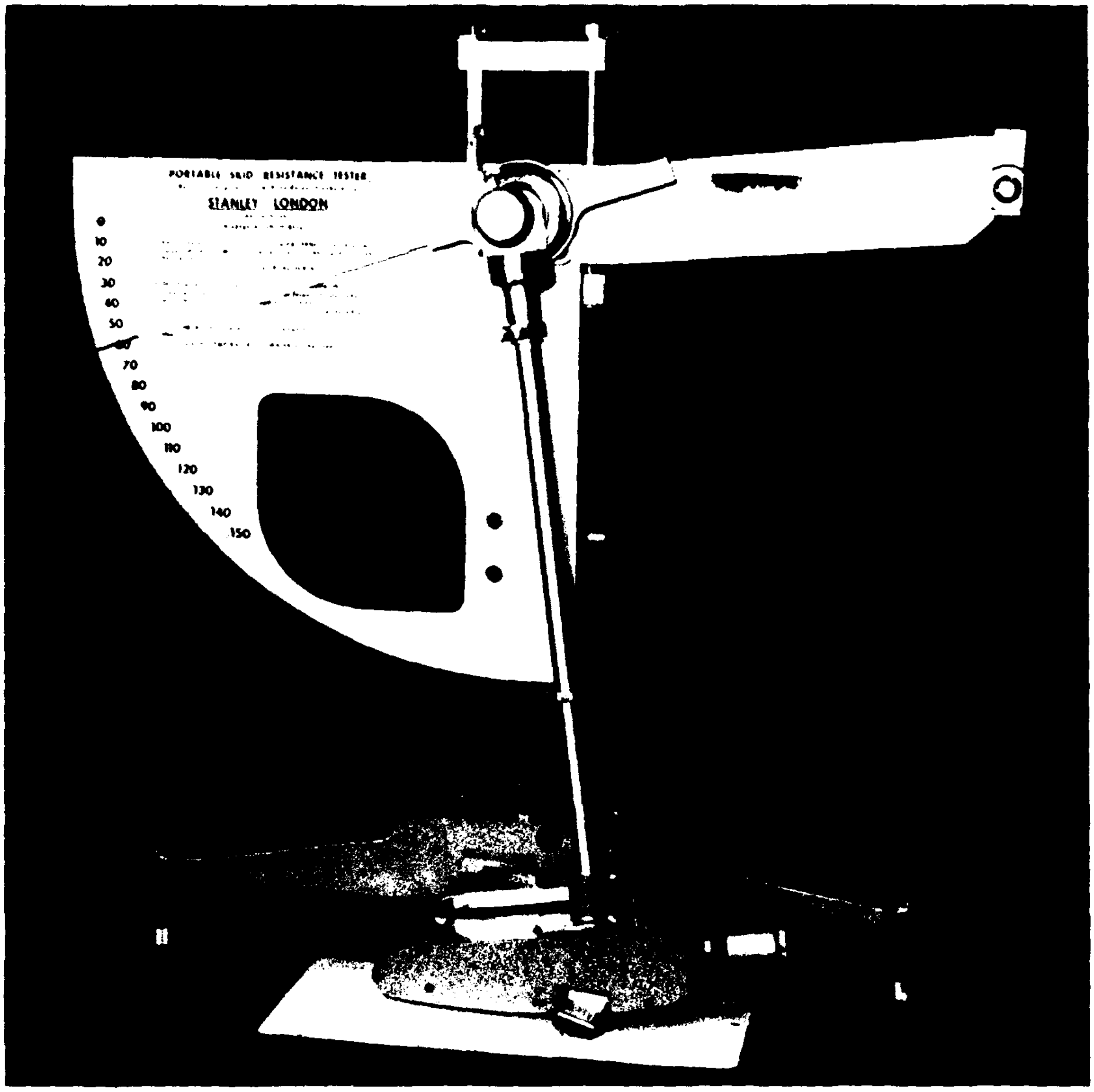

Figure 11. British Pendulum Tester.

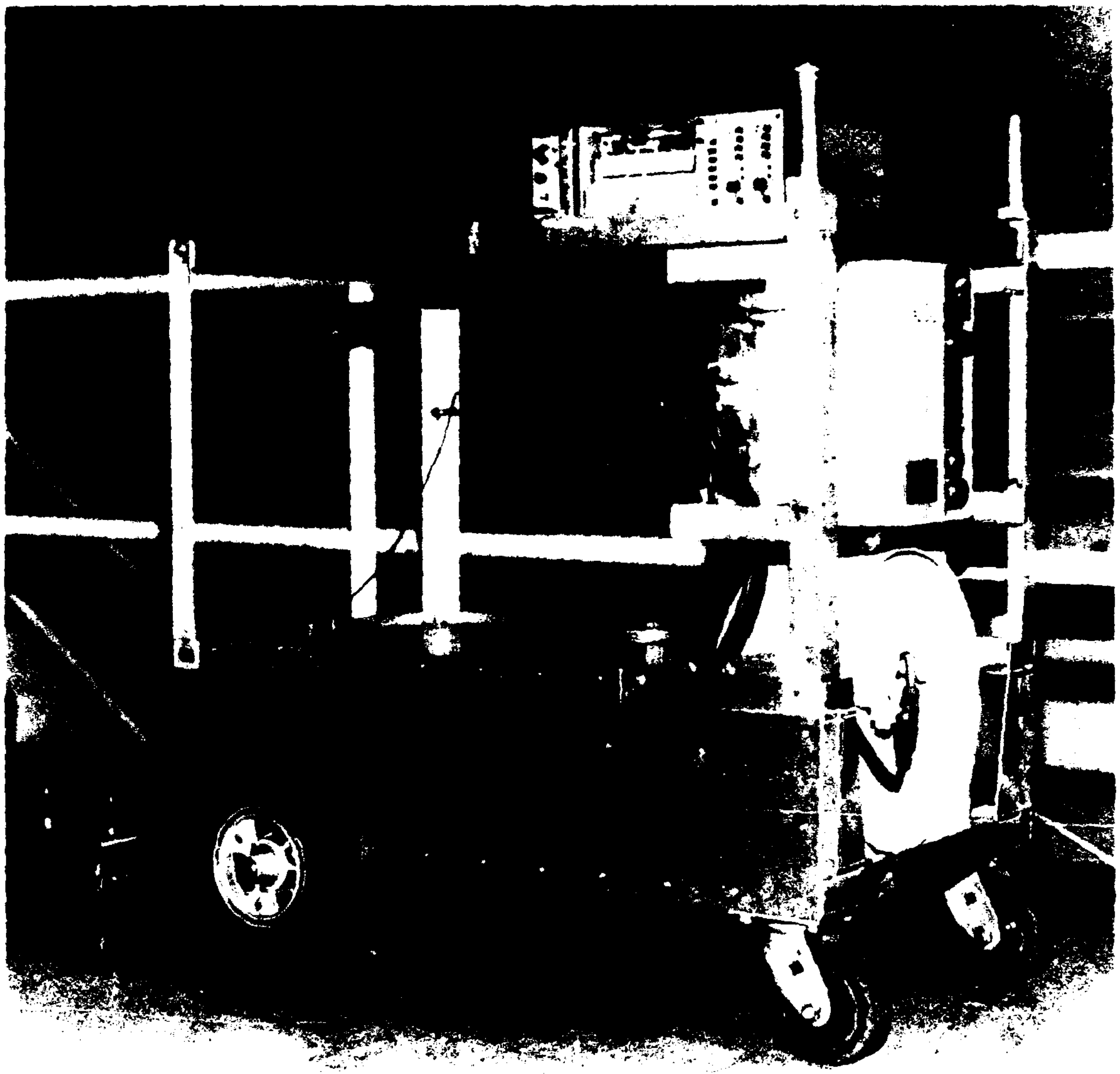

Figure 12. NCEL Slipmeter with heavy sled.

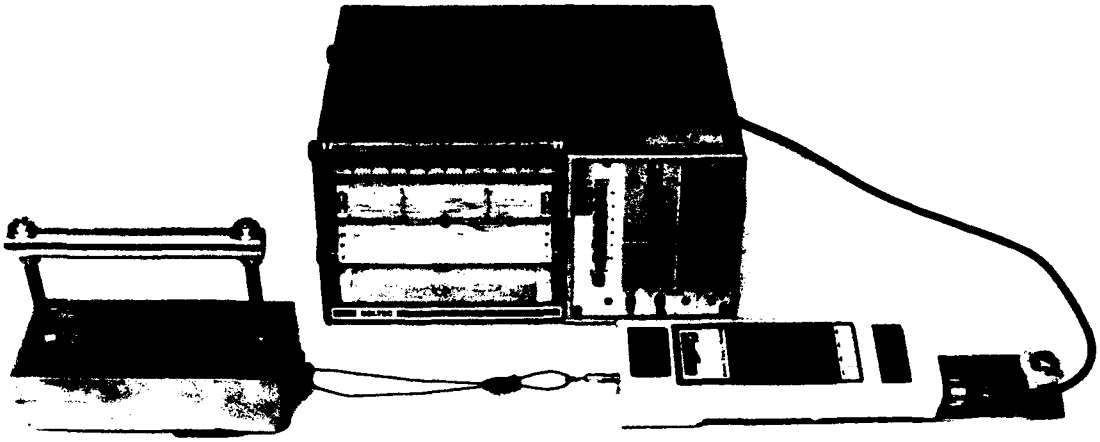

Figure 13. Light sled with instrumentation.

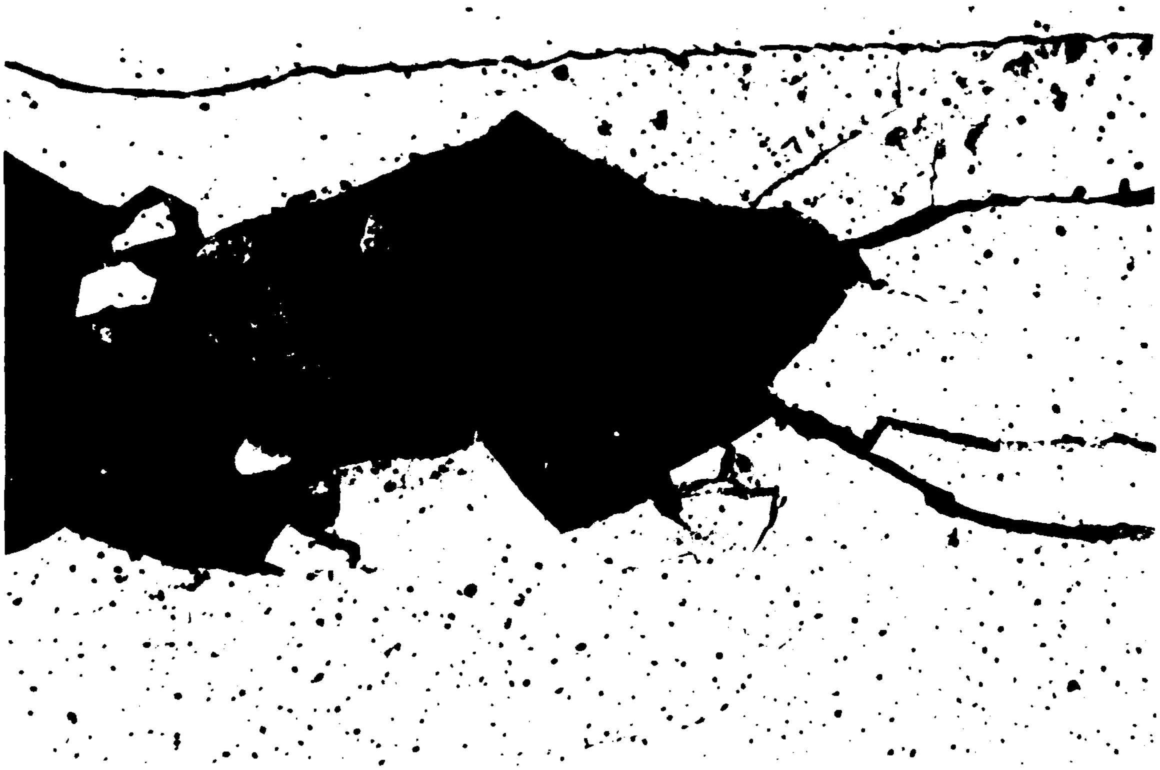

Figure 14. Crushed blister in organic topping.

Figure 15. Joint covered by thin-film coating system.

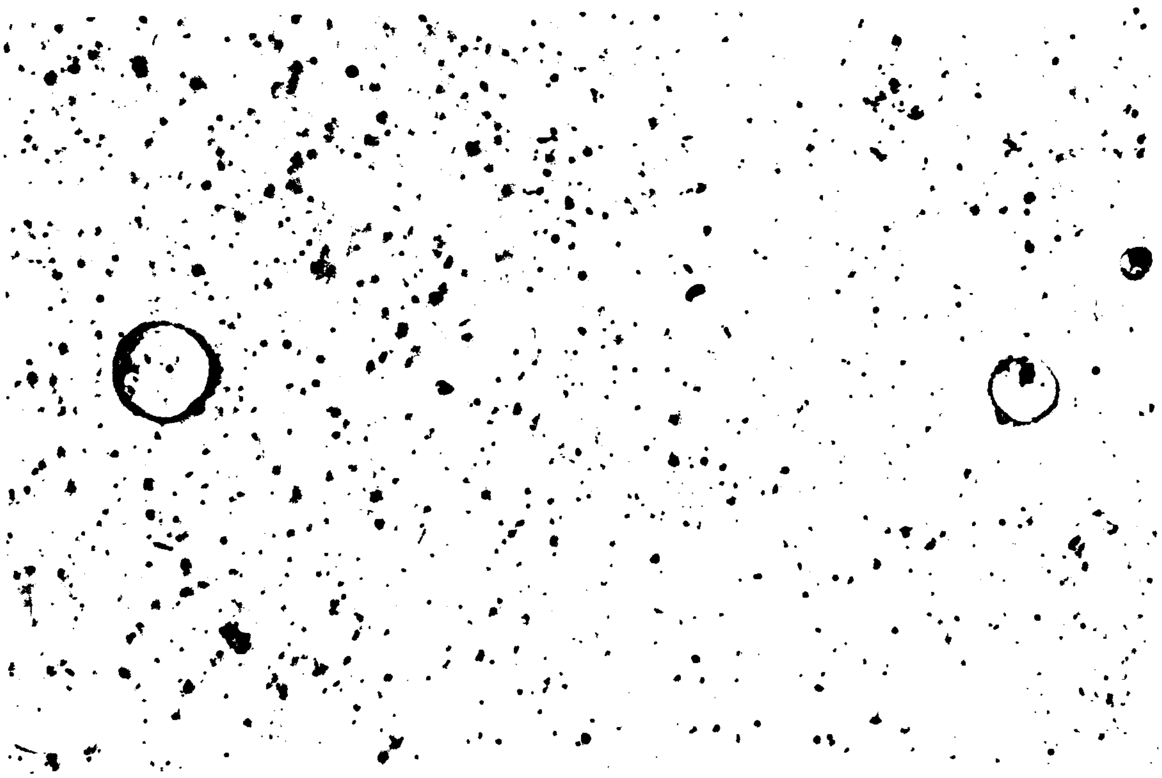

Figure 16. Pinholes in organic topping.

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